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MANUAL TRAINING IN THE SERVICE OF PHYSICS

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The purpose of the following article is to call the attention of American educators to a pedagogical movement in Germany which combines both in elementary and secondary courses instruction in physics and manual training. The writer became acquainted with the movement through contact with one of its leading exponents, Seminaroberlehrer O. Frey, through an inspection of the laboratory under his direction in the Leipzig Lehrerseminar, and through reading the book which he has prepared to be used as a teacher's manual and textbook for pupils.[1] This article will accordingly consist, first, in a discussion of the place and significance of the movement with especial reference to American conditions, and second, in a brief review of the book which represents it.

The general point of departure of the movement is suggested by the name—in German, *Arbeitsunterricht.* There is no English expression which is exactly equivalent to this, but it may be translated as instruction through work or constructive activity. The English word "work" has too much the special meaning of antithesis to play or idleness to serve as a complete translation of *arbeit. Arbeitsunterricht* in physics, as Herr Frey conceives it, may be described as instruction in physics through the production by the student himself of the apparatus to be used and the individual discovery, so far as possible, of the laws of the science. This method is contrasted on the one hand with mere instruction—that is, the communication of ready-prepared knowledge—since it encourages the student to investigate and determine for himself the uniformities of physical phenomena. On the other hand, it is contrasted with instruction *in* manipula-

[1] O. Frey, *Physikalischer Arbeitsunterricht.* Leipzig: Ernst Wunderlich, 1907, pp. 192.

tion or *in* manual activity. Manual activity is here the means and not the end. This procedure is, then, distinguished from the ordinary laboratory physics in that here the student produces the apparatus himself, and from manual training by the fact that the aim is not manual skill but an insight into physical laws. Or, to put it in another way, *Arbeitsunterricht* may be regarded as laboratory physics plus production of the apparatus; or as manual training plus the aim of gaining knowledge thereby —or more properly speaking manual training transformed by the fact that the aim is knowledge and not manual skill.

Besides being justified by the demand for concentration of the school curriculum and for economy of time this innovation seems to the writer to be further justified by a critique of the present methods of instruction in both physics and manual training, especially the latter. In this discussion secondary education is especially in mind, but the application may also be made to the higher grades of the grammar school.

First, in regard to physics. In this branch, as in allied natural sciences, the instruction has been revolutionized within the last few decades by the introduction of laboratory work. The merely descriptive textbook is either displaced by one which includes directions for laboratory experiments or is supplemented by a laboratory manual. In this newer instruction the student comes into direct contact with the processes about which he is to learn and thus gets an insight into them which only actual perception and manipulation can give. This principle so underlies all modern pedagogy that it needs no further justification.

The criticism of modern school physics which is made by Herr Frey, however, is that it does not carry this principle of first-hand acquaintance with the facts to its full extent. There still stands between the pupil and the elementary processes he is to investigate, no longer a mere verbal description, to be sure, but something which forms a considerable barrier to direct knowledge, namely, the apparatus. That is, for a complete understanding of the meaning of an experiment, one must have a complete understanding of the apparatus used. But when the stu-

dent is required to use a finished and more or less complicated piece of apparatus, he understands neither the construction of the apparatus nor the results which are obtained by means of it.

To overcome this difficulty, Herr Frey has emphasized two points: first, simplicity in the apparatus, and second, construction of the apparatus by the student himself. Simplicity of the apparatus has three advantages: First, it enables the student to grasp more easily the principle which underlies its use and thus to understand the results which are obtained with it; second, it makes possible the construction of the apparatus by the student himself; and third, it makes the cost of the apparatus so small that many schools which could not otherwise afford a physics laboratory can do so. Perhaps the greatest value of Herr Frey's book is the skilful elaboration of a course with very simple and easily constructed apparatus. The idea at the basis of the work is not altogether new, but its successful application is an important service to pedagogy as well as to physics.

The advantages in the construction of the apparatus by the student himself are discussed in the theoretical introduction to the *Arbeitsunterricht.* The chief stress is laid upon the importance of the motor sensations which result from the muscular activity. The point will be more fully discussed in the review of the book.

So much for the relation of the *Arbeitsunterricht* to instruction in physics. It is also related, as was already remarked, to manual training. The principles which justify manual-training instruction in the schools are not always clear in the minds of educators and of school officials. Two general tendencies, however, may be distinguished. The first is toward a manual training which has for its aim general knowledge and education to which it subordinates mere technical and manual skill. This tendency originated in the general movement toward self-activity in the Pestalozzian and Herbartian schools, and another expression of it is the kindergarten. In the kindergarten the aim of the multifarious activities is elementary knowledge of form, color, number, social relations, etc. This

sort of justification of manual work in the schools is the one commonly made by educational theorists and investigators. A notable example is the position taken by Professor Dewey in his *School and Society,* that elementary spinning, weaving, and other similar activities should be introduced into the elementary schools for the purpose of acquainting the child with the industrial processes which underlie modern civilization.

The second tendency is toward a manual training which has for its purpose the acquirement of a trade or at least the partial acquirement of a trade, and which therefore sets as its standard progress in manual skill and subordinates general knowledge and education. The discussion has here of course to do with manual training in the general schools. Special trade schools come under a different principle. This second conception of manual training in the common schools is the one which obtains in the minds of the general public, and, it must be confessed, of a very large number of school administrators. That such is the case is evident when one considers the manner in which manual training is carried out. The schools are furnished with elaborate shops and costly machinery. The pupils confine themselves for long periods of time to certain elementary manual processes until they are able to acquire a technical skill in them. At the end of a year, perhaps, they are able to show as evidence of their work a piece of furniture or some metal work. The goal has been reached by long-continued practice on the same simple process until it was perfected. If the object of manual training is technical skill, that object is reached, but if it is knowledge either of natural science or of industrial history the time is almost as good as wasted. The pupil has acquired art and not science; but the evidence of the attainment of the art is more easily comprehended by the average citizen than that of science, and it is the average citizen in whose eyes manual training is to be justified if money for its maintenance is to be obtained. As a result, manual training tends to take more and more a practical turn.

It is not the purpose here to argue in detail for the one type of manual training as against the other. It is sufficient to point

to the general consideration that the aim of the common school is to give a general education. To give a specialized training in a trade impairs the main work of the school. If the aim is general education, it can be brought about better in some other way. If the aim is practical, it is illogical and unjust to prefer one trade above another. Assuming the position then without further argument that the aim of the school is general education, it follows that manual training must be brought under this aim. It is this that Herr Frey does when he makes manual work a means to the attainment of knowledge of the fundamental laws of physics. In his own words: "Not merely to drill the pupil but to make him conscious of that which the drilling has effected, and to train him in the estimation of work values, must be the goal of such instruction" (p. 29.)

How this general principle is carried out we may best show by examining somewhat more in detail Herr Frey's discussion of the principles underlying the *Arbeitsunterricht.* In his "didactic-psychological" introduction, the author begins by tracing the recent development in instruction in physics and shows that it has been in harmony with the psychological demand, first, for *Anschaulichkeit* or direct presentation to the senses, and second, for a procedure which will bring into play the fullest activity of the pupil. The demand for sense presentation was met by the use of the stereopticon and of demonstration experiments in the classroom. But another step in advance was made when individual experimentation was introduced. At the same time emphasis was laid upon the quantitative aspect of experimentation. Now both of these later advances rest for their value upon the fact that they bring into play a hitherto neglected class of sensations, the sensations of movement. These sensations are essential to a complete development of space perception, for this development can only be brought about through movement. They are therefore essential to all measurement and estimation of distance. Their ordinary residue effects as "traces in memory with resonance properties" constitute an essential factor of all our apprehension of spatial relations.

The fact that it is a debated point in modern psychology

whether the value of active processes for experience consists in the sensations of movement or in some form of central organization which is the condition of the movements does not modify the importance of the active processes themselves. The author's theory is therefore on valid ground in its essential point, the emphasis on activity in the acquirement of experience.

The author next proceeds to show that the correct view of physics is not that of a series of objects existing beside one another—the static view—but rather that of a causal series of events—the dynamic view. If muscular activities are necessary in building up the concept of space as an extension, they are all the more necessary in building up the concept of space as a "field of force." By means of muscular activity we reach the concept of "mechanical work . . . . from which all physical instruction must take its departure." The concepts of two factors in mechanical work, mass and velocity, are developed from the sensation characteristics which arise from a muscular movement encountering resistance on the one hand and varying in the manner in which it is carried out on the other.

There is also a characteristic thought process (process of bringing concepts into relation) which is fundamental to physics and which is exercised when we carry out purposeful movements—that is, the process of estimation. An example of such estimation is that which a jumper makes when about to spring. It consists in a clear comprehension of the amount of muscular activity represented by movement sensations which is equivalent to a given amount of objective work. To develop the ability to make such estimations accurately—as, for example, when dealing with weights—is part of the business of physics instruction.

The writer would be disposed to take exception at this point to Herr Frey's psychology. The assumption that the estimation of distance in making a spring involves a thought process is an example of the psychology which reads into perception the logical relations which reflection may find involved in it. Perception is a much more direct process. But this process can be made the basis of reflective analysis. Here again, therefore, the

criticism does not essentially affect the validity of his method of instruction.

In general, then, the method of instruction here advocated is to put the pupil in such a situation that he experiences through his own bodily movements the phenomenon to be studied, and then to lead him to analyze his own experiences, and from this analysis work out a concept of the phenomenon. The way in which this analysis takes place appears more fully in the consideration of the separate large divisions into which physics is divided.

The order of treatment of the different divisions, as well as the manner of treatment, is determined by the character of the movements through which knowledge is gained. That is, the sensations of movement, as the author puts it, determine the choice and arrangement of material.

The first and fundamental concept according to this scheme is the concept of physical work. This should not, as is commonly done, be treated as a simple element, the variations of which are apprehended by the pupil as corresponding to the different degrees of exertion he puts forth, but should be analyzed into mass and velocity.

In a similar way the author takes up the concept of acceleration. This is to be taught, at first, not by means of a falling body, since the movement is too rapid to be apprehended, but by a blow as of a hammer. This is to be treated as a form of accumulation of work and to it can be related the accumulation of work in spring tension, loading of an electric battery, air compression, etc.

The next concept is that of a stream of work or energy, and this can best be formed through the perception of a flowing body, as of water or air. The concept then may be applied to the flowing of gases, of heat, and of electric currents.

The final main concept to be gained is that of oscillation or vibration. The starting-point for the apprehension of this form of work is found, as is commonly done, in the pendulum. But the analysis of the pendulum movement by means of geometrical projection is not used because this is too foreign to sensation

experience. An ingenious device for connecting the pendulum movement with a movement of the pupil consists in joining the pendulum by a rod to the pedal of a bicycle and first letting the pupil drive the pendulum by running the bicycle, and second letting the pendulum drive the bicycle.

The author treats also in his introduction the technique of instruction and of the preparation of the course. He takes up such questions as the teacher's relation to his pupils, the management of a class, the arrangement of a schedule, the procuring and making of apparatus, etc. The apparatus is developed on the basis of three simple pieces: the rod (*Stab*), the coupling-box (*Muffe*), and the axle (*Achse*). Suggestions are given finally as to fitting up the workroom. This section has many useful suggestions of a practical nature.

The second or practical part of the book consists in the details of a course of study based on the principles already laid down. As an illustration of the manner in which the exercises are elaborated, a description of the first exercise is given.

This lesson is entitled "The Windlass." The windlass is constructed in very simple form and consists of a cylinder of wood with a small hole through the center through which passes an axis of iron. The axis rests in slots or holes in two upright sticks, or in metal pieces fastened to the sticks, and the sticks are fastened at the bottom to wooden blocks. A crank handle is attached to the axis and with a string and weight the axis is complete. The instructor now directs the pupil to lift a weight with the windlass and leads him by means of the question-and-answer method to compare the force necessary to lift a weight with and without the windlass. This comparison is then made quantitative, but only by means of estimation. Application, through a series of questions, is then made to larger windlasses, and the pupil calculates how much he could lift with a large windlass made in the same way, and finally how much a man could lift. He is then told that there are windlasses with which a man can lift still greater weights. He fails to work out theoretically how this can be; so another windlass is constructed. This time it is a small model made of a cork cylinder, a knitting needle

for an axis bent so as to make a crank, and two pieces of bent tin for a support. For units of weight hairpins are used. The pupil is now led to discover through his own trial that a pin on the crank will balance two on the string. He next finds that one pin placed farther out on the crank will balance three, and so on. He then estimates the distances, and formulates the results into a table under the direction of the teacher, but is not given any theoretical discussion of the phenomena. He has, however, a direct understanding of the phenomena, and that in quantitative form.

To appreciate the skill with which the course is constructed, one must consult the author's own discussion, which seems to the writer to form a notable contribution to the effort to work out pedagogical methods based upon modern psychological knowledge.